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GROUP

CLASSIFICATION

# CANADIAN PATENT

LINER EXPANDER

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Granted to Pan American Petroleum Corporation, Tulsa, Oklahoma, U.S.A.

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PRIORITY DATE

No. OF CLAIMS

#### LINER EXPANDER

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This invention relates to a constant force spring device, and more particularly, to a device for expanding a metallic liner wherein an expanding die is urged against the liner by a constant force spring device.

Heretofore, a method and apparatus have been developed for installing an expanded metallic liner in an oil well or other conduit. Typically, a corrugated steel liner is inserted in a conduit which is to be lined, the greatest peripheral dimension of the liner being slightly less than the inside diameter of the conduit. An expanding tool is passed through the liner placed in the conduit, and a first-stage expanding die causes a gross plastic deformation of the liner, which is expanded outwardly against the inside of the conduit. A second-stage die on the tool then provides an additional finer deformation of the liner to provide a smoother, more finished surface on the inside of the liner and to assure more complete contact between the conduit and the liner. In a typical design of this type expanding tool, the frictional drag of the first-stage die supplies the expanding force for the second-stage die, which expanding force is a direct function of the strength, or wall thickness, of the conduit in which the liner is being installed. For example, in lining oil well casing, heavy wall casing may cause a very high frictional force which results in excessive pressure being required to push the expander through the liner. The application of the great forces required may result in rupture of the casing or in breaking the installing tool. In instances where the internal diameter of the conduit is somewhat less than that anticipated, the resulting forces can cause the tool to become stuck in the casing, or otherwise cause damage to the casing and the tool. In other designs, such as where a cantilever spring arrangement is employed in connection with the secondstage die, various difficulties are encountered in obtaining a spring mechanism having the desired strength in combination with the other spring characteristics, and with the tool dragging against the inside wall of the conduit after being passed through the liner.

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Since tools of the type mentioned above often are employed in wells deep in the ground, it is highly preferable that a tool be used which under no circumstances will become stuck in the well or cause damage to the well. Any such trouble occurring in a well can result in considerable loss in time and great expense in making repairs.

An object of the present invention is a device for applying a constant force to an expanding die or other similar apparatus so that a preselected maximum force is exerted against a work piece. Another object is an improved expanding tool for installing metallic liners in a conduit, which expanding tool can apply no greater than a predetermined force to the liner being installed in the conduit. Still another object of the invention is an economical and easily fabricated constant force spring device. A further object is a rugged, easy-to-operate expanding tool employing such a spring device. These and other objects of the invention will become apparent by reference to the following description of the invention.

In accordance with the present invention there is provided a constant force spring device which comprises a body member, an elongated column element adjacent said body member, bearing plate members contacting the two ends of said column at least one of said bearing plate members being longitudinally movable in respect of the other and stop means on said body member to limit the deflection of said column element to prevent permanent deformation of said column element upon the application of a compressive load thereto. In one embodiment of the invention, the foregoing constant force spring device is employed in a tool for expanding a metallic liner inside a conduit, said constant force spring device being positioned on said tool to urge an expanding die member against the liner being installed in the conduit by a substantially constant force.

My invention will be better understood by reference to the following description and the accompanying drawings wherein:

Figures 1A, 1B and 1C, taken together, constitute a partial cectional view of a preferred embodiment of a liner expanding tool according to the present invention; and

Figure 2 is a sectional view of the apparatus of Figure 1A taken at line 2-2; and

Figure 3 is a typical plot of applied Load versus Deflection for the constant force spring device of the invention.

Referring to the drawings, Figure 1A is the bottom portion of a liner expanding tool for use in installing a metallic liner in a well, while Figure 1B illustrates the middle section of such a tool and Figure 1C represents the upper section of the tool. The expanding tool 11 is attached to standard well tubing 12 by coupling 13 and, typically, may be lowered from the surface through a well casing (not shown) to a point in the casing at which it is desired to install a metallic liner. Before inserting the tool into the well, an elongated vertically corrugated liner 14 fabricated from mild steel, or other suitable malleable material, is placed on the tool. The corrugated liner is secured in position by contact at its upper end with a cylindrical shoulder member 16 and, at its lower end by contact with a first-stage expanding die 17 in the form of a truncated circular cone which serves as a firststage expanding die in the manner hereinafter described. The expanding die is fixedly attached to a centrally located, elongated cylindrical hollow shaft 18 which forms a portion of the body of the tool. As shown, the expanding die 17 is held in place between a lower shoulder 19 and collar 21 threaded onto the shaft. A plurality of movable arms 22, preferably provided with outwardly enlarged portions 23 near the top, are disposed in the form of a cylinder around shaft 18. The enlarged portions of the arms 23 upon being moved outwardly contact the liner to perform the final step of expanding the corrugated liner into a substantially cylindrical shape. The arm members 22 are pivotally attached to the shaft so as to be movable outwardly from the shaft by a tapered expanding member 24 slidably positioned on the shaft to serve as a second-stage expander. The surface of the member 24, as shown, moves upwardly along the shaft to engage with the arms and move them outwardly. Advantageously, the inside surfaces of the arms 22 and the outside surface of expanding member 24 form mating sections, typically octagonal in shape. The expansion of the arm members is controlled by the position of the member 24 which moves upwardly

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until it contacts shoulder 26 provided on the shaft. As member 24 moves in a downwardly direction arms 22 fold invardly toward the shaft. The expanding arms 22 are held in place on the shaft by collar 27 and circular groove 28 provided on the shaft.

The expanding tool, comprising the first-stage die and the secondstage die is drawn through the liner to expand it in place in the casing. The
first-stage die provides a gross deformation of the liner so that it is
expanded outwardly against the wall of the casing. The second-stage die then
passes through the liner and performs the final expansion to smooth the inner
surface of the liner and to provide more even contact between the liner and
the wall of the casing and effect a fluid-tight seal.

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In operation, the liner setting tool is assembled at the surface, as described above, and a glass cloth saturated with a resinous material may be wrapped around the corrugated tube to form the liner. The assembly is lowered into the well at the location at which the liner is to be set. A liquid, such as oil, is then pumped under pressure down the well tubing and flows through the passageway 29 provided in polished rod 31, through ports 32 and into cylinder 33 connected to the upper end of the shoulder 16. Upon the application of fluid pressure to the cylinder, the piston 34 secured to polished rod 31 moves upwardly in cylinder 33. As shown, rod 36 connects polished rod 31 and shaft 18 upon which is mounted the first-stage expanding die 17. When the piston 34 moves upwardly through the cylinder 33 the expanding die 17 and the secondstage die 22 are drawn upwardly into the corrugated liner 14 and "iron out" the corrugations in the liner, so that the expanded liner may contact the inside wall of the casing in which it is being installed. Positioned on the shaft below the expanding member 24 is a constant force spring member 37 which is employed to urge the expanding member against the expanding arms 22 with a substantially constant force. The force exerted against the arm members being substantially constant, the force transmitted through the arm members to the liner and to the casing will be substantially constant so that either sticking of the tool in the casing or rupture of the casing is precluded. Of course, the force provided by the spring member is preselected so that the frictional

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forces between the tool and the liner and the pressure exerted against the casing are maintained at predetermined safe levels. The constant force spring member assures that the contact pressure between the liner forming portion 25 of the arms 22 is great enough to provide the desired deformation of the casing, while preventing damage to the casing or to the tool.

The constant force spring member 37 is slidably mounted on the shaft 18 and held between the expanding element 24 and a cylindrical lower shoulder member 38 forming a portion of a differential screw element 39 which transmits the loading on spring member 37 to shaft member 18. The differential screw element comprises shaft member 18 on the outside of which are cut male threads 18a, the lower shoulder member 38 provided with female threads 38a and thimble member 41 provided with threads 41a and 41b on the outside and the inside, respectively, to engage with threads on the shaft and the shoulder. The two sets of threads are coarse, such as square, modified square, or Acme threads, to withstand very high loads and differ in pitch so that shoulder 38 is moved upwardly on the shaft 18 when the shaft is revolved relative to thimble 41. The shoulder 38 is secured to the shaft 18 by splines 45 so that it can slide longitudinally, but it is not free to rotate on the shaft. Fixedly attached to the lower end of the thimble is a friction member, such as bow springs 42, a hydraulically actuated friction pad, or other such device for frictionally engaging with the inside wall of the conduit to secure the thimble against rotation with respect to the shaft. Preferably, the direction of the shoulder member threads 38a is the same as that of the shaft threads 18a, e.g. righthand threads, and the pitch, or lead, of threads 18a is slightly greater than that of threads 38a, with the pitch ratio being close to unity. In this manner, clock-wise revolution of the shaft relative to the thimble causes shoulder member 38 to advance upward slightly and a compression load is exerted upwardly on spring element 37 to cause buckling. For example, one satisfactory differential screw was made up using five and one-half threads/inch square threads on a shaft approximately 1.7-inch outside diameter and five and threequarters threads/inch square threads on a shoulder approximately 2.5-inches inside diameter.

Constant force spring element 37 comprises column element 43, advantageously consisting of a plurality of elongated columns disposed around shaft 18. Upper bearing plate member 44 is in contact with the upper ends of the columns and is slidably positioned on shaft 18 to transmit the force of the spring longitudinally against the bottom end of expander member 24. Lover bearing plate member 46 contacts the lower ends of the columns and is moved upwardly along the shaft by longitudinal movement of lower shoulder 38 as a result of revolving differential screw element 39. Grooves 47 are provided in each of the bearing plates, to form an upper race and a lower race, into which the ends of the columns are inserted. These grooves may be shaped to conform with the shape of the column ends if desired. A cover 48 may be employed to exclude foreign matter from the spring mechanism and to protect the spring.

A means for limiting the deflection of the columns is required. Although the column element functions in a buckled condition, application of excessive compressive load thereto would cause total failure or rupture of the columns. Therefore, a pair of stops 49 and 49a are provided for this purpose. As shown, the stops are rigidly connected to the bearing plates, and, in effect comprise upper and lower limiting sleeves positioned on the shaft to slide longitudinally thereon. The ends of the stops may move toward, or away from, each other as the load on the spring member varies. Lower sleeve 49a is prevented from moving down by lower shoulder 38 connected to the shaft 18. However, the spacing between the ends is such as to limit the longitudinal travel of the bearing plate members as they move together to prevent permanent deformation of the column element 43. Various alternative means for preventing damage to the column element may also be employed. For example, pins or rings mounted on the shaft may serve as stops, or the cover 48 provided with suitable connections may be employed for this purpose to limit longitudinal and/or lateral deflection of columns.

The columns of the column element 43 may be arranged around the shaft 18, which as shown here forms a portion of the body of the spring device, with ends of the columns fitted in the races 47. The columns may be

fitted closely together as shown, or may be spaced around the race, with separators used between them to maintain the desired spacing. The number of columns employed will depend upon column characteristics and the materials of construction. For example, the slenderness ratio of the column may be varied widely, and the column ends may be round, flat, fixed or hinged. The preferred construction is a thin, slender column with rounded ends, free to move within the races shaped to the curvature of the column ends. Materials which may be satisfactorily employed for the columns are carbon and low alloy steels, chromium and nickel-chromium stainless steels, various copper base alloys, such as phosphor bronze, beryllium copper, the high nickel alloys and other similar materials providing satisfactory mechanical properties. Typically, the individual columns are of long rectangular cross-section, with the width being greater than the thickness, and arranged so that the wider face of the columns is normal to the diameter of the shaft. Thus, with sufficient compression loading, the columns buckle, and bend about the axis having the least moment of inertia, e.g., outwardly away from the shaft ld.

For example, a group of columns 0.167-inch thick by 0.438-inch wide by 10.626-inches long, with the ends rounded, were fabricated from A.I.S.I 4340 steel, quenched and drawn at 575°F. Each column was found to require a 20 critical compression loading of 450 rounds in order to buckle the column. After buckling, the columns were found to have a very flat spring characteristic, as shown in Figure 3, wherein  $P_{c}$  is the critical buckling load and point C represents the load and deflection at which the stress in the extreme fibers of the column exceed the yield point of the material. Theoretically, the shape of this spring characteristic curve is described by curve OA'ABC. Actually, this curve is described by OABC due to friction in the system. Points A and B represent typical working limits, which, of course, may be varied according to the application for which the spring is designed. For example, where a large number of flexing cycles are not anticipated, a working stress just below the 30 yield point may be used, while with a great number of flexures, the working stress may be held to less than the endurance limit of the material of construction. In the above-mentioned tests, the lateral deflection was limited to

approximately one inch, at which the longitudinal deflection was approximately: 0.225 inches. From zero deflection to the maximum deflection, the 450-pound loading was found to be substantially constant.

In another test a spring device was built, as shown, employing 20 columns, each having a critical buckling load of 1250 pounds. The lateral deflection was limited between 0 and about 1.00 inches by appropriately positioning the stops. Upon compressional loading, the spring element buckled at substantially 25,000 pounds and from a longitudinal deflection of 0.04 inches (buckling) to about 0.15 inches the load remained substantially at 25,000 pounds.

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Of course, in designing a spring element as above it is advantageous to obtain the greatest possible value of longitudinal deflection for specified values of lateral deflection and critical buckling load, while maintaining the stress level in the columns at a safe level. The preferred columns, therefore, are laminated, as shown in Figures 1B and 2, with multiple flat members making up each column.

In the operation of the above expanding tool for setting a liner in well casing, the made-up tool is lowered into the well as mentioned above, with the arms 22 in the retracted position. When the tool is at the desired level, the well tubing is revolved. The friction member 42 engages with the wall of the casing and prevents thimble 41 from revolving. With several revolutions of the tubing, lower shoulder 38 is moved upwardly by differential screw 59 to buckle spring element 37 which has a predetermined critical buckling load. This load is transmitted upwardly against the lower end of expander 24, and its tapered surface is engaged with the tapered surface on the inside of the arms 22 to urge the arms outwardly with a substantially constant force proportional to the critical buckling load of the spring element. Subsequently, the expanding tool is passed through the liner to expand it in the casing in the manner described hereinbefore.

The foregoing description of a preferred embodiment of my invention has been given for the purpose of exemplification. It will be understood that various modifications in the details of construction will become apparent to

the artisan from the description, and, as such, these fall within the spirit and scope of my invention.

#### I CLAIM:

- l. A device for expanding a metallic liner inside a conduit which
  device comprises a shaft element, an expanding die member attached to said
  shaft element, said die member comprising a movable liner-forming member
  positioned on said shaft and being radially movable in respect thereof to
  contact said liner, an expander member slidably positioned on said shaft
  between said shaft and said die member to move said liner-forming member
  from said shaft, and a constant force spring member positioned on said shaft
  to contact said expander member and to maintain said expander member against
  said liner-forming member, whereby said liner-forming member is urged against
  said liner by a substantially constant force.
  - 2. In a device for installing an expanded metallic liner in a conduit wherein an expanding die is moved through a liner positioned in said conduit to expand said liner: a cylindrical shaft element, an expanding die member attached to said shaft, said die member comprising a plurality of arm members disposed around said shaft and being pivotable cutwardly therefrom to contact said liner, a cone member slidably positioned on said shaft between said shaft and said arm members to urge said arm members outwardly from said shaft, and a constant force spring member positioned on said shaft to contact said cone member and to maintain said cone member in contact with said arm members, whereby said arm members are urged outwardly by a substantially constant force.
  - 3. The device of Claim 2 wherein said constant force spring member comprises a plurality of columns disposed around said shaft, a first bearing plate member and a second bearing plate member, each of said bearing plate members contacting opposite ends of said columns, at least one of said bearing plate members being movably positioned on said shaft and being in contact with said come member, stop means connected to said shaft to limit the axial travel of said movable bearing plate member along said shaft, and compression means for maintaining a lateral deflection in said columns.

- 1 4. The device of Claim 3 wherein said compression means comprises
  2 a differential screw connecting said spring member and said shaft.
- 5. The device of Claim 3 wherein said stop means comprises a sleeve-like element connected to said movable bearing plate member and slidably positioned on said shaft and a member connected to said shaft to limit the travel of said sleeve-like element.
  - 6. The device of Claim 3 wherein said columns have a rectangular cross-section, the width being greater than the thickness, and having the wider face normal to the diameter of said chaft.
  - 7. A device for installing an expanded metallic liner in a conduit which comprises a cylindrical shaft element; an expanding die member mounted on said shaft, said die member comprising a plurality of arm members disposed circumferentially around the outside of said shaft and being pivotable outwardly therefrom to contact the liner; a conical expanding member slidably positioned on said shaft between said shaft and said arm members to urge said arm members outwardly from said shaft; a plurality of slender columns, each having a long rectangular cross-section and disposed circumferentially about said shaft; an upper bearing plate member and a lower bearing plate member, each slidably positioned on said shaft and contacting opposite ends of said columns; limiting sleeves attached to each of said bearing plate members and slidably positioned on said shaft; a shoulder member on said shaft; a differential screw element connecting said shoulder and said shaft to apply a buckling load to said columns; said shoulder being engageable with the limiting sleeve connected to said lower bearing plate member, whereby the axial travel of said bearing plate members is limited; said column members transmitting their buckling load to said arm members to urge said arm members outwardly with a substantially constant force.

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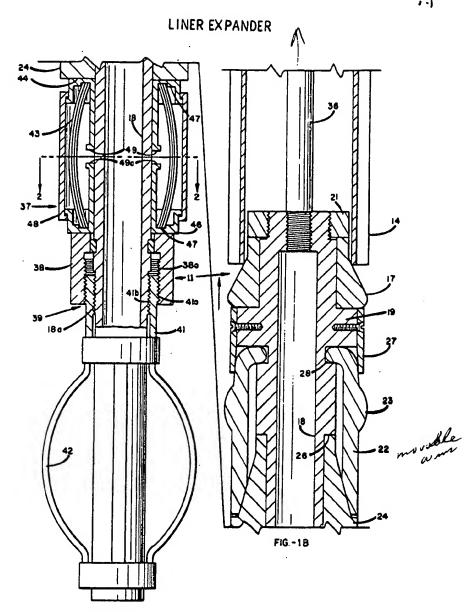
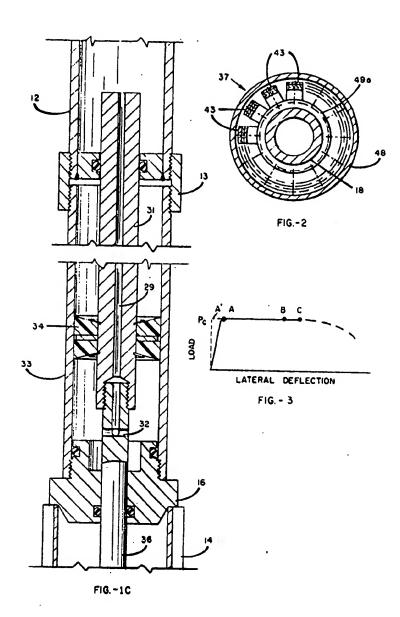


FIG.-1A



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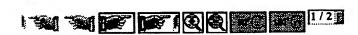
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E. In a device for installing an expended metallic liner in a conduct wherein an expending die is moved through a liner positional in said someths to exceed will liner; a cylindrical start almost, as according die meeter attached to said shaft, said die meeter comprising a plusality of any meeter attached to said shaft, and does not being plyotable extensity therefrom to contact said liner, a come meeter plicably positioned on said shaft between said shaft and meeters to varp said are ammeers consactly frue said shaft, and a constant force opting number positioned on said staff to contact said come member and to exist are members, whereby said some member in contact with said are numbers, whereby said some someters are urged comparedly by a substantially constant furce.

3. The fevice of Claim 2 shands said constant force spring contermongeties a plumility of commes disposed account wild shaft, a filest bearing plate seaber and a second bearing plate scatter, each of said bearing plate scattery contecting opposite cots of said columns, at least one of said learning plate numbers being reveally resistened on said what's and being in contact with said come number, stop means connected to said starts to limit the axial travel of said scoutce bearing plate number along said start, and compression means for maintaining a lateral derivotion in said columns.

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- 5. The device of Chain 3 wherein anid along means comprises a alsowe-like element commerced to said movehic tenering place member and stiffship positioned on said shaft and a sunface communication ends about to limit the travel of said alsowe-like element.
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- 7. A device for installing an expended estallis liner in a conduit which comprises a sylindrical shaft classes; on accounting the senter sounded on said shall, said the sensor comprising a planelity of are someon disposed diremetarentially around the outside of eald shaft and bed-og pluotable metmarily therefrom to soutest the liner; a scalest expending master slidsbly positioned on said short between said shaft and maid are explored to turn smill re orthancey from suid abelt; a plurelity of siencer columns, canb bawing a long reutangular onces-section and disposed streamerstably shout said chalt; an upper bearing plate number and a lower tearing plate master, ob sizesity positioned on sais staft and contactive opposite onto of said my limiting alseres whiseded to each of sold bearing plate numbers and alidably positioned an maid statts a shoulder number on such shafts a differential serve alreads econosting out shoulder and said should be apply skiling look to skif enimmes said thoulder being companied with the limiting sies to commuted to entil later bearing plate mester, whereby the arial travel of said bearing plate members in limited; said column vesters branesicting their buckling lood to exid any numbers to urgs said any modern estimately with a substantially communications.

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My invention will be better understood by reference to the following description and the economycaying drawings wherein

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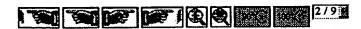
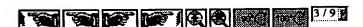




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Figure ) is a typical plot of applied lock versus Deflection for the constant force spring device of the Lavention.

Referring to the drawings, Figure 14 is the lotton portion of a liner expending tool for one in installing a motalile liner in a well, while Figure 18 Libertrates the middle section of semb a tool and Figure 10 repremeats the upper sertion of the tool. The expending tool il is ablashed to stantard well tabing 18 by compling 15 and, typically, may be lowered from the surface through a well ensing (not shown) to a point in the souring at which it to sective to invisit a metallic liner. Defore inserting the test into the well, an alongsted vertically corregated liner in Chiricated from mild steel, or other suitable mileable material, to placed on the tool. The corrupted liner is secured in position by contact at its upper end with a cylindrical shoulder names 16 and, at the lower and by contact with a first-stage expansiing dis 17 in the form of a tromosted circular cone which serves as a firsteding die in the server bareinefter described. The espending die is fixedly extended to a controlly located, elongated cylindrical hollow shaft lô which forms a portion of the body of the tool. As shows, the expending Sic 17 20 is hald in place between a lower shoulder 19 and coller 21 threaded onto the short. A plurality or morphia arms 89, preservably provided with enteredly sularged portions 85 mear the top; we disposed in the form of a splinker around shaft 18. The unlarged purbloss of the stree 23 spot being soved outvarily excises the liner to purform the final step of expending the convented limer into a substantially splintrical shape. The are seafters HE are pivotally etisched to the sheft so as to be movehly outcomely from the sheft by a tapared expending member 26 slikebly positioned on the sheft to serve as a second-stage expender. The earliess of the masker th, as shown, moves spreadly along the shart to sugage with the arms and more than outwardly. Advantageously, the 30 incide surfaces of the area 62 and the outside curface of expanding member 25 form setting sentions, typically cotegonal is shape. The expectation of the arm members is controlled by the position of the member 20 raich moves upwardly





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The expending tool, comprising the first-stage die and the secondstage die is drove through the liner to expend it in place in the content. Du first-stage die provides a grote deformation of the liner so that it is expended externily against the well of the seeing. The second-stage die then passes through the liner and performs the final expension to smooth the inner section of the liner and to provide more even content brisess the liner and the well of the caring and effect a finid-tight soal.

In operation, the liner setting tool is assembled at the surface, as described shows, and a glass cloth saturated with a revidence material may be exapped around the corrugated late to form the liner. The assembly is lovered into the well at the Legation at which the liner is to be set. A Liquid, such so oil, is then pusped under pressure down the wall inhing and flows through agreeny 29 provided he polished rod 51, through parts 52 and into epileder 35 completed to the upper and of the shoulder 16. Upon the application of field pressure to the cylinder, the piston 34 secured to polished red 31 moves operally is sylinder 35. As shows, not 36 cornects polished not 31 and sheft 18 spon shigh is nowbed the first-stage expending dis 17. Thus the piston N neves upwardly through the splinder 33 the expending die 17 cml the secondstage die 22 are draus upwartly into the corrugated liner 18 and "iron out" the sorregations is the limer, so that the expected liner may combot the theride wall of the casing in which it is being taxtalled. Positioned to the shell below the expending member 26 is a constant torce spring number 37 which is employed to trips the expending number against the exploding sters 22 with a substantially sometant force. The force exarted against the are secular being substantially constant, the force transmitted through the arm members to the No liner and to the during will be substantially accordant as that either sticking of the tool in the casing or repture of the casing is precluded. Or course, the three provided by the spring meter is preselected so that the frictional

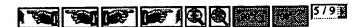


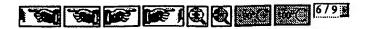
and the many the residence of the complete participation of the first of the contract of the c



forces between the tool and the liner and the presence emerted agether the ensing are extended at presentered od safe levels. The constant force spring manher namers that the contact presence between the liner forming portion 25 of the arms 22 is great ecough to previde the desired deformation of the contact line, while preventing demand to the saming or to the tool.

The constant force spring sasher 77 is alide'sty nounted on the shart 15 ced hald between the expending alseant 25 and a sylistrical lower checker master 35 forcing a portion of a differential error alseast 39 which truscate tan looking on spring number 77 to chart master 15. The differential error alseast comprises shaft number 15 as the certific of which are one sale threads like, the lower shalder master 35 provided with tends the are not sale threads like, the lower shalder master 35 provided with tends threads 35 and thinkle master 51 provided with threads had one fall on the certains and the lands, respectively, to sepace with threads on the shaft and the shoulder. The two cets of threads are source, such as aquare, solidist square, or fone threads, to witnessed are source, such as aquare, solidist square, or fone threads, to witnessed are source, such as aquare, solidist square, to witnessed with shaft 15 was the shaft in revolved relative to thinkle \$1. The checker 36 is secured to the shaft is revolved relative to thinkle \$1. The checker 36 is secured to the shaft if the shaft. Finally arisohed to the lower end or the thinkle is a friction master, such as two aprings \$2, a aptractically equated friction past, or other such device for frictionally employed to the instale will of the encircle to eccure the thinkle squaret transfer with reveals 36, is the same as that of the chart threads 16, e.g. right—land threads 36, with an pitch revise being alows to unity. In that master threads 36, with an pitch revise being alows to unity. In that master was made up using five and one-half threads/inch square threads on a chart approximately 1.7-inch outside dissector and five and (arester threads) such as expression love a solution of another threads on a chart approximately 1.7-inch outside dissector and five and (arester threads) such as and approximately 2.5-inches and the shaft approximately 2.5-inches





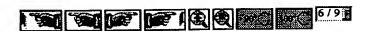
Constant force spring element IT comprises unlies element \$3, siventageonally convinting of a plurality of elemented column displaced around short

18. Upper bearing plate number the in to contact with the apper ends of the
actual and is elifabily positioned on shart if to transmit the force of the
spring longitudinally against the bottom and of expender colors of. Lower
bearing plate number to contacts the lover main of the columns and is moved
towardly along the shart by langitudinal movement of local smoulder \$8 on a
result of revolving differential surer element \$9. Grooves if are provided
in such of the bearing plates, to form an upper race and a lower race, into
which the costs of the columns are inserted. These grooves may be chapted to
confurn with the shape of the column such if sacired. A cover 48 may be
employed to another foreign matter from the spring mechanism and to protect
the coriner.

A seems for limiting the defination of the columns is required. Although the column element functions in a backled sendition, application of . properly sumpressive load thereto would sense total failure or repture of the so. Therefore, a pair of stope by and itse are provided for this purpose. As shown, the stope ere rigidly connected to the bearing plates, and, in effort comprise upper and lower limiting slacres positioned on the shaft to alide longitudinally thereon. The under of the stops may move toward, or many from, each other so the look in the spring number vertes. Lover slaves bys ented from moving down by lower abundan 36 someoted to the shart 18. r, the spacing between the ands is much as to limit the longitudinal travel of the bearing plate members on they move together to prevent perman deformation of the column almost \$3. Warrows alternative means for preventing stanage to the column element may also be employed. For example, pink or rings someted on the chaft may serve as stops, or the cover 48 provided with suitable communices may be amployed for this purpose to limit longitudinal and/or lateral seffection of columns.

The columns of the column classest 45 may be arranged errord the sparing shart 16, which as shown here force a partion of the body of the spring flavor, with each of the columns fitted in the reces 57. The solumns may be

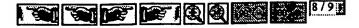
- 6 -





ritted closely tognitur as shore, or way be spaced around the race, with separators used between these to meiatoin the desired spacing. The reshar of columns employed will depend upon column absentantiate and the emistrials of construction. For example, the standarders ratio of the column may be varied widely, say the column made say be round, flat, first or himsel. The preserved construction is a thin, element column with tousded ands, free to move within the recess shaped to the excessive of the solumn made. Materials which may be astimized with employed for the solumn area or north and low alloy steels, chronius and mindul-shronius stainless steels, various support bear allique, such as presented became, beryllius support, the high stokel alloys and other miniture materials providing satisfactory mechanical properties. Typically, the individual columns are or long rectangular cross-section, with the table being greater than the thickness, and arranged so that the wider face of the columns is somewall to the simulator of the about. Thus, with surficient compression lossing, the columns buckle, and tend shout the said heving the loss's owner of inertia, e.g., outeratly may from the shart 18.

For example, a group of columns 0.167-inch thick by 0.438-inch wide by 10.626-inches long, with the ends rouwish, were febrioated from L.f.S.I \$360 steel, quenched and drawn at 575°F. Buth column was found to require a critical suspension loading of \$50 pounds in order to bankle the addust. . After builling, the selmes were fruit to have a very flat spring characteristio, as shown in Figure 3, wherein  $P_{\alpha}$  is the critical backling load and point atio the load and deflection at which the stress is the extreme fibers alumn usesed the yield yount of the untertal. Theoretically, the shape of this spring characteristic ourse is described by entre Ca'ABC. Actually, Cols curve is described by CASC due to friction in the system. Potente A and B represent typical straing limits, which, of course, may be varied according to the application for which the spring is designed. For example, where a le number of Chexing spoise are not empioisated, a working stress just below the 30 yield goint may be used, while with a great number of flexures, the working my be held to less than the enforcement limit of the saterial of scort tion. In the above-munificed tests, the lateral marketion was limited to



approximately one inch, at which the longitudinal deflection was approximately 0.225 lackes. From were deflection to the accison deflection, the \$50-pound loading was found to be substantially constant.

In emother test a spring device was built, as deven, employing 80 columns, each having a critical buckling load of 1050 possés. The internal deflexion uses limited between 0 and about 1.00 inches by empropriately positioning the stope. Open compressional loaning, the spring whemset buckled at admirtantially 25,000 possés and from a longitudinal deflexion of 0.00 inches (bushling) to stook 0.15 inches the load remained substantially at 25,000

Of course, in conjusting a spring closure as above it in advantagements obtain the greatest possible value of longitudinal defination for specified values of laboral deflection and artical bushing load, while unintending the stress level in the columns at a cafe level. The professed columns, therefore, are laminated, as shown in Figures 18 and 2, with multiple flat suntare united as each column.

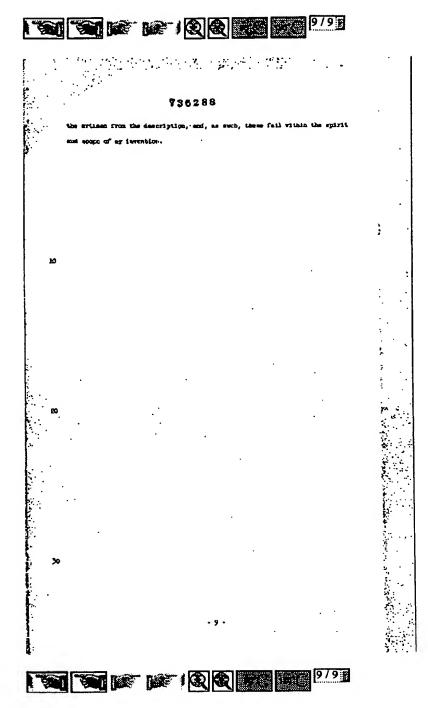
In the operation of the shows expending tool for setting a liner in well excised, the mede-up tool is lowered into the sell us sectioned above, with the ares 22 in the retreated position. Thus the tool is at the desired level, the well tolding is revolved. The friction number of capages with the wall of the manny and necessity than it is nowed appearably by differential revolutions of the taking, lower shoulder 35 is moved appearably by differential server 39 to bush is opening almost 37 which has a predefendional critical buckling lower. This last is transmitted severally against the lower and of expender 36, and its topered surface is engaged with the tapared surface on the inside of the error at to urgs the terms outserfly with a substantially constant force proportional to the critical buckling load of the spring element. Extensionally, the expending tool is passed through the liner to expend it in the caping in the meaner described hereabefore.

the foregoing description of a preferred embeliance of my investion.

Let the purpose of assumilification. It will be understood that various manifications in the detects of assumination will become apparent to

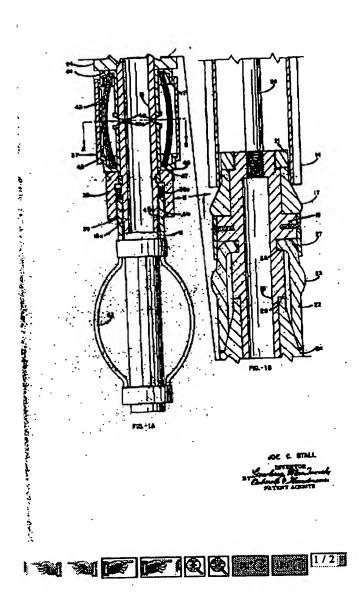
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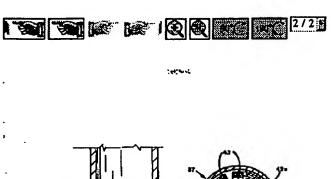
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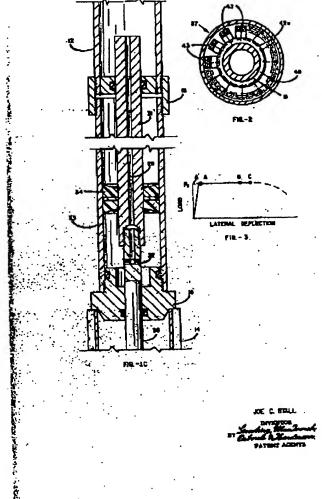


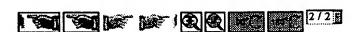


TUNK!









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